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IMPLICATIONS OF REQUIRING NEW PRODUCTION OF OLDER AIRCRAFT TYPES (LESS THAN 75,000 POUNDS) TO MEET AMENDED NOISE STANDARDS

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C.F. Day
E.D. Studholme
J.C. Jones

J. Watson Noah, Inc.
5205 Leesburg Pike, Suite 510
Falls Church, Virginia 22041

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16. Abstract

The study examined the implications of requiring new production of older business jets to meet Stage 3 noise standards. Most current production business jets are well below these standards. Aircraft that may be in production after 1985 which do not meet Stage 3 noise limits include the G.E. powered Learjets and the Gulfstream 3. Both companies have conducted extensive noise reduction programs and, except for reengineering, application of known technology will not lead to significant noise reductions. Reengineering appears to be impractical since use of an available alternative engine would have a major impact on aircraft performance and mission characteristics. Significant reductions in noise footprint can be achieved by means of noise abatement flight procedures. Use of new production models of these aircraft in the post-1985 time period is not expected to have major community noise impacts particularly at airports with 50 or more air carrier departures per day. Such airports account for about 94 percent of the U.S. population impacted by 30 NEF or more.

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I. INTRODUCTION AND SUMMARY

The purpose of this analysis conducted by J. Watson Noah, Inc. (JWN) was to examine the Costs and Benefits of Requiring New Production of Older Small Jet Aircraft (less than 75,000 pounds) to Meet Amended Noise Standards. The general approach was as follows: (1) identify current production aircraft which do not meet Stage 3 standards, (2) examine potential noise reduction measures and estimate the cost of applying each to the candidate aircraft, (3) develop single-event contours for the existing and modified aircraft, (4) compare costs and benefits (area reduction) of making the modification, and (5) estimate the community impacts associated with the modification.

The original study plan could not be completed. Only two aircraft types, the Learjet 24/25/28/29 series using the General Electric CJ610 engine and the Gulfstream 3 using the Rolls-Royce Spey engine, were identified as candidate aircraft.[1/] The GE Learjets have been in production since the early 1960s while the Gulfstream 3 is a derivative version of the mid-1960 Gulfstream 2. Both manufacturers have had active noise reduction programs and JWN could not identify further applications, except reengining the aircraft, which would reduce noise emissions significantly. Reengining, while technically feasible, would so alter the basic performance characteristics of the aircraft that both would lose the special features which were attractive to users. The evidence available indicates that there is no economically feasible technology that would lead to significant reductions in noise emissions for these aircraft.

1/ Certain versions of other aircraft series which used older engines such as the CF700 do not meet Stage 3. In all such cases, the manufacturer is producing a similar model using a modern engine that will meet Stage 3. Models using older engines were excluded from this analysis.

Because of this, the planned cost-benefit analysis could not be completed. The study, instead, has concentrated on the potential implications, in terms of noise impacts, of allowing these two aircraft to operate after 1985. The study therefore examines the potential post-1985 market, where these aircraft are likely to fly and the number of operations they will perform, their noise impact in comparison to other aircraft, and methods for reducing noise emissions through improved flight procedures.

POTENTIAL MARKET

The Gulfstream 3 is perhaps unique among the larger business jet aircraft because of its range and speed capabilities. Although the aircraft is in flight test, the program has been launched successfully with more than 50 firm orders on hand. A total production run of 250 aircraft is possible.

The GE Learjets are also unique. This small business jet flies higher and much faster than its major competitor, the Cessna Citation, and despite higher fuel consumption, is preferred for many missions. The continued escalation of fuel costs may dampen the demand for these aircraft. Learjet is producing an aerodynamically improved version of this aircraft (Models 28/29) but only five were in the United States inventory as of January 1980. We expect that deliveries in the post-1985 time period will not be significant.

PRODUCTION, MARKETING AND USE OF BUSINESS JETS

The market for business jets can be characterized as small compared to the market for jet transports. In addition, new programs are difficult to launch because aircraft are usually sold one at a time to individual customers. For these reasons, both engine and aircraft producers concentrate on derivative programs rather than the development of all-new engines or aircraft. As a result, the spectrum of available engines in the thrust range suitable for business jets is quite limited.

About 90 percent of the general aviation jets in the United States inventory are used for business flying. Corporate operations generally use these aircraft to extend the commercial system rather than to compete with it. About 40 percent of business flights involve the pick-up or delivery of passengers at an air carrier terminal. The balance of the flights are split about evenly between general aviation and air carrier airports.

Business jets, on the average, operate about 600-700 hours per year with approximately 600 departures per year per aircraft. This compares to about 3000 hours per year for a 727 transport and about 2,400 departures.

BUSINESS JET AIRPORTS

There are 177 Gulfstream 2 and 450 GE Learjets in the United States inventory. The Gulfstreams are located at 58 airports around the country, 15 of which are major air carrier hubs, 15 are other air carrier airports and 28 are general aviation airports. The largest concentrations of Gulfstreams are at Westchester County Airport, White Plains, New York (26), Teterboro, New Jersey (17), and Houston International (9).

The 450 GE Learjets are based in more than 200 cities (exact airport locations are not available) with the largest concentration in Dallas (25), Houston (24), and Fort Lauderdale (16). Since there are several airports in each of these areas that can be used by these aircraft, the Learjets are much less concentrated than the Gulfstreams. Only 31 of the 200 cities listed are those with major hub airports although many more of the communities are in large metropolitan areas.

The dispersion of these aircraft coupled with their relatively low utilization rates must be considered when assessing community noise impacts. Assuming aircraft delivered in the post-1985 time period are based at locations similar to today's, these jets may not create serious noise problems. Airports like Westchester County and Teterboro are, of

course, exceptions, but the population of business jets at these airports includes many other types besides those analyzed in this study.

NOISE IMPACTS

The Gulfstream 3 will have FAR 36 values that differ very little from the Gulfstream 2 for sideline and takeoff, but will be much quieter (9.9 dB) on approach because of aerodynamic improvements and the resultant reduction in approach thrust. The original Gulfstream 2 was a very noisy aircraft with an impact area at 105 EPNdB equalling a DC9. The Gulfstream 3, at maximum takeoff weight, is 4 to 5 dB quieter than the Gulfstream 2, due primarily to the "hush kit" equipped Spey engines. This results in a 55-60% reduction in impact area for all EPNdB values examined (85 to 105 dB in 5 dB increments). The same aircraft, using a Gulfstream developed noise abatement procedure gives an additional 24% reduction at 100 EPNdB and over 51% at 85 EPNdB. At 50,000 pounds, the takeoff weight for a typical 1500 mile flight, the Gulfstream 3, using this procedure, closely approximates the noise levels of an A300 -- the quietest aircraft in the transport fleet.

Like the Gulfstream 2, the GE Learjets are quite noisy and generate contour areas comparable to the DC9-30. Only one flight procedure was analyzed because no abatement procedures were available from the manufacturer. Thus, the contours shown in Appendix A are not directly comparable.

COMMUNITY IMPACTS

Community impacts are measured in terms of the number of takeoff and landing cycles (LTO) -- defined as one takeoff and one landing -- required to increase noise levels by 1 dB at classes of airports. The results are as follows:

- Major hubs or airports with 250 more air carrier departures per day. 940 Learjet or 1120 Gulfstream LTOs per day are required to generate a 1 dB impact. JWN estimates that these airports account for 62% of the total national population exposed to 30 NEF or greater.

- Large Air Carrier Airports having 50 to 249 air carrier departures per day. 190 Learjet or 300 Gulfstream LTOs per day are required to increase noise by 1 dB. These airports account for about 32% of the national population impacted by 30 NEF or more.

- Medium Air Carrier Airports having 20 to 49 air carrier departures per day. About 35 Learjet or 70 Gulfstream LTOs are required to increase noise by 1 dB. These airports account for less than 4% of the population impacted by 30 NEF.

- Small Air Carrier Airports having 5 to 19 air carrier departures per day. About 4 Learjet or 12 Gulfstream LTOs are required to increase noise levels by 1 dB. These airports account for less than 3% of the population impacted by 30 NEF.

CONCLUSIONS

Available information suggests that neither the Learjets nor the Gulfstream can achieve significant reductions in noise levels through technology. The use of noise abatement procedures, at least for the Gulfstream, can reduce footprint significantly. Further, use of these jets under present conditions are unlikely to cause significant noise impacts at airports with a reasonable degree of air carrier service. The Learjet, using standard flight procedures, does result in impacts at small airports but the total population impacted will be small in relationship to the national total. This factor is offset somewhat since the number of new Learjets added to the fleet in the post-1985 time period is expected to be small.

II. STUDY APPROACH

OVERVIEW

The purpose of this study was to identify the costs and benefits of requiring new production of older business jets to meet Stage 3 noise standards. A careful review of noise emissions at certification points reveals that only two types, the Learjets powered by the CJ610 engine and the Gulfstream 3, do not already meet Stage 3. Some versions of other aircraft, mainly those using the low-bypass ratio CF700 engine, do not qualify, but in each case the producer has plans for, or is delivering a model using the TFE731 engine that does qualify. CF700 aircraft were therefore not included in this analysis.

The Gulfstream 3 is an advanced derivative of the Gulfstream 2 which was first delivered in 1967. The Gulfstream 2 was very noisy and over the years has received extensive modification for noise abatement. These modifications have been incorporated into the new aircraft. Similarly, the Learjet, first delivered in 1964, has been modified for noise abatement purposes. Thus, reengining appears to be the only noise reduction option open to these producers.

There are, however, only a few engines available in the thrust ranges used on general aviation jets. Both candidate aircraft have unique operating characteristics which allow them to fill special missions in the spectrum of business jets that no other current or planned aircraft can do as well. Engineering studies done by the producers indicate that a reengined version of either aircraft cannot meet existing performance levels so that these special characteristics would be severely degraded. Reengining, therefore, was judged to be economically impractical.

Since no noise reduction technology is practical, JWN concentrated on examining other means for lessening noise impacts -- the use of noise abatement flight procedures. In addition, the airports most likely to be impacted and the potential community impacts were assessed.

CANDIDATE AIRCRAFT AND TECHNOLOGIES

It is apparent from a review of existing FAR 36 Stage 3 noise standards that most business jets already comply. A problem exists with only those models using jet or low-bypass ratios for engines. Of these, the major concern is with the top and bottom ends of the size range, namely, the Learjets using the CJ610 engine and the Gulfstream 3 using the Spey. All medium-sized jets using the TFE731 are quieter than existing Stage 3 limits.

Aircraft not achieving existing Stage 3 noise limits are as follows:

	Approach	Sideline	Takeoff
Learjet 25	X	X	X
Learjet 24	X	X	X
Falcon 20	X		X
Sabre 75A	X		X
Learjet 35 & 36	X		
Gulfstream 2		X	X

Note that the Learjet 35 and 36 fail to qualify on approach by only about 1 dB and easily meet the limits for the other reference points. The Falcon 20 is 5 dB over Stage 3 on approach, more than 1 dB under for sideline and about 1 dB over on takeoff. The Sabreliner 75A, which uses the CF700 like the Falcon 20, misses both approach and takeoff limits by about 2 dB. The Gulfstream 2 is about 9 dB over the sideline limit and 2 dB over the takeoff limit. The Learjet 24 is at least 2 to 3 dB above the limits at each reference point.

The medium-sized Falcon 20 and Sabre 75A were excluded from serious noise analysis for two reasons: (1) both producers have announced plans to market an aircraft with a high-bypass ratio engine which should easily qualify, and (2) there are a variety of other aircraft available to users

which have similar characteristics. The Learjets and the Gulfstream 2, however, have unique characteristics unmatched by any other aircraft available or in development.

The last Gulfstream 2 (G2) was produced at the end of 1979 and the first two vehicles for the Gulfstream 3 (G3) program are undergoing flight tests. The G3 is not expected to meet Stage 3 limits, particularly for sideline noise. This study will therefore consider the G3 and the Learjets (using the General Electric CJ610 engines).

The G3 is a derivative of the G2 which incorporates new wing technology to enhance range capability and fuel efficiency. Like the G2, it will use the Rolls Royce Spey engine and include the "hush kit" installation used on the G2. It appears, therefore, that there is little in the way of new technology than can be applied to reduce G3 noise emissions. There is some possibility that Rolls-Royce may continue development of an improved mixer for the Spey engine, but JWN does not believe that this development program will be conducted to support the G3 alone. At best, the G3 will require approximately 500 engines. A mixer development program is too expensive to be funded for such a small potential market.

The GE powered Learjets have been in production for many years and until the advent of the Cessna Citation were the most popular business jet aircraft ever produced. The CJ610 engine is a pure jet with relatively poor fuel efficiency compared to more modern fan engines. The engine does have a superior thrust-to-weight ratio and is simple and inexpensive to maintain. The Learjets therefore, can fly higher and faster than many other business jets and the higher fuel costs are somewhat offset by lower operating and maintenance costs for many applications. Because of this, the standard Models 24 and 25 and the aerodynamically improved Models 28 and 29 have remained a significant portion of total Learjet deliveries.

The Learjets, like the G2 and G3, have already been quieted to the extent feasible as long as the same engine is used. JWN therefore concludes that the only technology available for reducing aircraft noise levels is the use of an alternative engine. These possibilities, along with some other factors influencing new engine selection, are discussed in the next section.

PRODUCTION, MARKETING, AND USE OF GENERAL AVIATION JETS

The first jet aircraft suitable for business use were designed in the late 1950s or early 1960s. All of the early programs benefited from government participation. In the United States, Rockwell designed the Sabreliners to meet Air Force UTX Program goals, while Lockheed (Georgia) designed the JetStar to meet the Air Force requirement for a four-engined jet utility aircraft (UC/X Program). Similarly, the success of the Hawker Siddeley HS125 program was assured by an early order for 20 aircraft by the Royal Air Force, and the Falcon 20 produced by Dassault and Sud Aviation also received government support. The first aircraft designed and produced specifically for the business market were the Learjet Model 23 and the Jet Commander Model 1121, both of which were successfully flown in 1963.

Aircraft engines have a similar history. The earliest U.S. engines, the CJ610, JT12, and the CF700, are civil versions of successful military engines. Later engines are also derivatives -- some of military engines and others of successful turboprop engines. This situation reflects the engine producers' view of the business jet market. The costs of new engine development are high, and the market is relatively small. Hence, no new core engines have been developed specifically for this market.

At the present time, four U.S. producers (Gulfstream American, Gates Learjet, Rockwell, Cessna) and three foreign companies (Dassault, British Aerospace, Israeli Aircraft Industries) are producing small jet aircraft. The Canadair Challenger, Dassault Falcon 50 and the

Mitsubishi Diamond are in development. For convenience, production aircraft can be classified as follows:

Small

Learjet 24/25/28/29
Citation I & II
Diamond I
Corvette

Medium

Learjet 35/36
Learjet 55/56
Sabre (all models)
Falcon 10, 20
HS 125
IAI Westwind

Large

Gulfstream 3
Challenger
Falcon 50

The size categorization of aircraft is useful in analyzing the airframe engine combinations that are possible. In general, there are very few engines available for aircraft in each size range: the JT15 and CJ610 for small aircraft, the CF700, ATF3, and TFE731 for medium aircraft and the Spey MK511, M45, ALF502 and CF34 for large aircraft.[1/] Of engines currently available, the CJ610 is pure jet, the CF700 and Spey are low-bypass ratio while the remainder are medium- to high-bypass ratio in nature.

1/ The M45 rated at 7,600 pounds was used on the now defunct VFW614 transport while the CF34, rated at 8000 pounds, is not actually used on any production aircraft although proposed for a growth version of the Challenger. The Rolls-Royce RB401 remains in the pre-development stage and its future was judged too uncertain for consideration in this study. IHI, Ltd. of Japan has announced the planned development of a 3600-pound thrust engine to be available in 1985.

Approximately 90% of the small jet aircraft operated in the U.S. are used for executive or business transportation. Not unnaturally, the manufacturers tend to optimize those design parameters desired by corporate users. In general, these include:

- Field length
- Range
- Cruise speed
- Altitude
- Payload.

Although the parameters can be optimized in different combinations, choices are limited by engine availability. Thrust ranges are as follows:

JT15	-	2,500 pounds
CJ610	-	3,000 pounds
TFE731	-	3,600 pounds
CF700	-	4,500 pounds
ATF3	-	5,050 pounds
ALF502	-	7,500 pounds
CF34	-	8,000 pounds
Spey MK511	-	11,400 pounds

Marketing Business Jets

Business jets are generally sold one-at-a-time to individual customers. This fact, coupled with large development costs for a new aircraft, forces producers to concentrate on derivatives of existing aircraft rather than radically new designs. A careful survey of potential customers is in order to determine the flight characteristics that are most attractive to the potential users.

This is an important consideration when analyzing potential technology applications for noise reductions. A change that enhances performance at reasonable costs is, naturally, more attractive than one which degrades performance -- the degradation may cause the aircraft to lose its special characteristics which allow it to be successful in the market place.

Learjet 24/25 Experience

The availability of alternative engines and thrust differences alone do not fully describe the difficulties of substituting one engine for another on a given aircraft. Two examples, based on data supplied to the JWN staff for an earlier study,[1/] illustrate the complications that can occur. The original application of the TFE731 was intended to be a simple replacement of the CJ610 on the Learjet 24/25 model aircraft. As the engine evolved, its size and weight caused the relocation of most aircraft equipment to maintain the aircraft center of gravity. Airframe weight was increased to maintain payload. The resulting aircraft, the Learjet 35/36 model, although undoubtedly influenced by the marketing consideration for coast-to-coast range, was significantly larger than the 24/25 and, in fact, competed with other medium-sized jet aircraft.

Learjet also performed engineering studies using the JT15 engine on a Series 24/25 airframe. The resulting aircraft could not approach the actual CJ610 model in performance and instead, could best be classed as a heavy and expensive Cessna Citation.

1/ "Economic Impact of Emission Standards For Small Jet Engines," Logistics Management Institute, December 1977, prepared for EPA under Contract 68-01-4647.

Medium Aircraft Experience

The experience cited above illustrates the difficulty with reengining a small jet aircraft. The situation is different for medium-sized aircraft. Several models have been reengined from the older engines to the TFE731. These included the HS125 which used the Rolls Royce Viper engine, the Westwind 1124 which used the CJ610 and the Sabre which used the JT12 or CF700. The Falcon 20 Guardian (a civil version of the USCG aircraft) will use the ATF3. Despite this, CF700 powered, medium-sized aircraft are still being produced. Installation of improved lift devices has resulted in reduced fuel consumption and active retrofit programs for some CF700 models have been successfully launched.

Large Aircraft Experience

The Gulfstream 3 is the only current production large aircraft which is not required to meet Stage 3 noise limits. The Lockheed JetStar II, no longer in production, was reengined when the four JT12 engines were replaced with four TFE731 engines. Furthermore, an active retrofit program for JetStars is in progress and many of the JT12 aircraft have been updated to the TFE731 configuration. The Falcon 50, a new aircraft which will be required to meet Stage 3, uses three TFE731s.

The Falcon 50 has been successfully launched and the JetStar, although out of production, is expected to remain in the active inventory of business jets for some time. This suggests that a three or four engine Gulfstream 3, which met both design goals and noise limits, would be acceptable in the market place. The problem is, however, that no aircraft, in the business jet size range, meets the Gulfstream design goals without using the Spey engine.

Planning and preliminary design work on a successor to the Gulfstream 2 began in the middle 1970s. Surveys of potential customers showed that increased range (transoceanic) airline speed and reliability, a cruise altitude of at least 40,000 feet and short field capabilities were

important considerations. At the same time, Gulfstream 2 operators were expressing interest in modern high-bypass ratio engines reflecting both the success of the TFE731 on small business jets and the proliferation of wide-body airliners.

Engineering studies by Gulfstream found no combination of available high-bypass ratio engines that yielded an aircraft meeting the desired flight characteristics. The differences between airliners and business jets help explain why this occurred. The airliner is sized to carry a large payload in relation to total aircraft weight. The aircraft is designed to produce minimum seat-mile costs usually leading to a minimum wing sizing based on fuel requirements which yield wing loading in the order of 120 pounds per square foot. High lift devices are added to achieve desired performance. This high wing loading dictates optimal cruise altitudes of 30,000 to 35,000 feet, since the best altitude is related directly to cruise ambient pressure which, in turn, is proportional to wing loading.

The business jet, on the other hand, besides being much smaller, also has a low payload relative to total aircraft weight. Wing size, like the airliner based on fuel considerations, is relatively larger with lower wing loading (75 pounds per square foot). The lower wing loading leads to reduced cruise ambient pressure and higher cruise altitudes -- more than 40,000 feet -- for maximum lift/drag ratio and minimum cruise thrust requirements. Thrust required is, in fact, proportional to weight and inversely proportional to lift/drag ratio. These characteristics, pressure/altitude requirements and fuel/payload characteristics, greatly influence engine/airframe matching -- in particular bypass ratio.

Gulfstream engineering studies, which have been reviewed at least in part by JWN,[1/], show that none of the available engines could be used

1/ Some information provided to Gulfstream by engine producers was regarded as proprietary and could not be released to JWN.

in two, three or four engine combinations to obtain an aircraft meeting Gulfstream 3 specifications. Achieving the proper engine/airframe match and cruise thrust/weight ratio at 40,000 feet meant a four-engine configuration. The resulting aircraft would be significantly overpowered for the airport performance required. Gross weight would increase to near 75,000 pounds and total fuel required would be 10-15 percent greater than the Spey-powered Gulfstream. An aircraft with three high-bypass ratio engines would require a 20 percent increase in cruise thrust, could not meet speed on altitude goals, and would weigh more and burn more fuel than the Spey aircraft.

A performance comparison of the Challenger and the Falcon 50 to the Gulfstream 3 tends to confirm these engineering studies, although neither aircraft was designed for the specific Gulfstream mission. On a payload-range basis, neither the three-engined (TFE731) Falcon or two-engined (AFL502) Challenger approach the 1600 pound-3700 mile transoceanic capability of the Gulfstream. The Challenger E using the CF34, which may be available in the future, appears to meet this requirement. Moreover, since thrust decays more quickly for high-bypass than low-bypass ratio engines, both the Challenger and Falcon have poor short field capability and experience great difficulty in attaining cruise altitude under ISA + 10^{o}C conditions.

The Spey-powered Gulfstream 3, therefore, fills a unique role among large business jets. This view is confirmed in the market place since the program has been successfully launched with more than fifty orders, with deposits, booked at this time.

The Use of Business Jets

Many of the largest and most influential industrial, commercial and financial organizations in the world use company-owned jet aircraft to enhance profitability. About one half of the industrial companies included in the Fortune 1000 list use business jets. Jet operators also

include the leading retail company (Sears Roebuck), the four largest commercial banks (Bank America, Citicorp, Chase Manhattan and Manufacturers Hanover), a leading diversified financial organization (Travelers Corp.), the largest non-airline transportation company (Union Pacific), the largest insurance company (Prudential) and the largest utility (AT&T).

Not all corporate users of jet aircraft are among the lists of giants. A review of the membership list of the National Business Aircraft Association (NBAA), covering 60 companies (not in the Fortune lists) for which financial data was readily available, showed that 49 percent had sales less than $50 million, 23 percent had sales between $50 and $100 million and 28 percent had sales greater than $100 million. The large companies include major firms in the engineering-construction field such as Fluor, Brown and Root and Bechtel, food wholesalers like the Fleming Company; hotel chains like Hilton and Holiday Inn; and retail store operators like C.R. Anthony and Dillard.

Corporations generally treat aircraft as any other asset -- they are expected to earn a return. Quite obviously, corporate jets cannot compete with airlines on an out-of-pocket cost per passenger mile basis. Most companies contend, however, that corporate jets reduce total travel time; provide effortless travel as opposed to crowded terminals, perhaps inconvenient schedules and long waits for baggage; and comfortable working conditions enroute. These factors tend to increase executive efficiency and productivity.

Business aircraft are used to augment rather than replace the commercial transportation system. NBAA estimates that about 40 percent of corporate flights are to pick-up or deliver personnel to connecting commercial flights. About 35 percent of all flights are to and from airports with no air carrier service.

NOISE IMPACTS OF BUSINESS JETS

Single event contours using standard takeoff and landing procedures were developed for both the Learjet and Gulfstream 3 aircraft. These show that both are comparatively noisy when compared to smaller jet transport aircraft. Normally, in a study like this, before and after modification contours could be compared. This cannot be done, however, because JWN could identify no feasible technology that could be applied to either aircraft which would allow it to compete for its special market in the spectrum of business jets.

Single event contours, by themselves, do not always give the best indication of potential noise impacts. Both the frequency and location of the events are important considerations. In addition, community impacts of noisy aircraft can be reduced by using safe (but different for standard) noise abatement flight profiles. Furthermore, at least in the case of the Gulfstream,[1/] significant noise reductions have been achieved over time. For these reasons, the JWN analysis included the following steps:

(1) Identification of airports (to the extent feasible) where Learjet and Gulfstream aircraft are based.

(2) Construction of single event contours using the Integrated Noise Model for:

  (a) early untreated G2 at gross takeoff weight (GTOW)

  (b) G2 with "hush kit" at GTOW

  (c) G3 at GTOW

  (d) G3 at GTOW using a noise abatement procedure

1/ Gulfstream submitted a substantial body of data to JWN for use in this study. Learjet, although invited to participate, chose not to submit any new material.

(e) G2 and G3 flying a typical (1500 mile) mission using a noise abatement procedure

(3) Analysis of potential community impacts of Learjet and Gulfstream operations.

(4) The degree to which Stage 3 limits could be reduced and still allow current production aircraft (except for Learjet and Gulfstream) to comply.

The results of these analyses are discussed in the next chapter.

III. STUDY RESULTS

This chapter develops single event contours for the candidate aircraft and assesses the potential community impact of continued aircraft operation. The post-1985 market for the G3 and Learjets is examined along with aircraft utilization rates and airports served.

POST-1985 MARKET

The G3 program has been successfully launched. If the design characteristics are demonstrated in the flight test program, sales over the last half of the decade can be expected. The G3 will basically appeal to the same group of companies that use the G2, that is, companies national or international in scope. A list of G2 operators reads like a Who's Who of the U.S. business and commercial world. A total program buy of 200 to 250 aircraft is possible and JWN estimates sales of 15 to 20 aircraft per year in the post-1985 period.

It's harder to predict potential sales for the GE Learjets. Historically, these aircraft have been used by corporate, air taxi (charter) and flight instruction organizations. The aircraft are relatively inexpensive to buy, easy to maintain, and provide performance characteristics (speed and altitude) unmatched by their closest competitors. Continued escalation of fuel costs may, however, inhibit future sales.

In general, the market for business aircraft is healthy and most analysts are projecting continued growth particularly for the more sophisticated business aircraft. Airline deregulation is, in the short run, stimulating increased use of business aircraft since major airlines are reducing the number of cities served and the commuter industry is having growing pains. JWN expects that this added stimulus will be dampened out by 1985 as the commuter industry matures. The non-jet business fleet and the commuter fleet have many aircraft in common so

that many business travelers are accustomed to flying in commuter type aircraft.

If a post-1985 market for the GE Learjets exists, it is likely to be quite small. Continued production, given a market, can be expected because of the high degree of commonality between the GE and Garrett models.1/

BUSINESS JET AIRPORTS

Most business jets are based and operate to and from major population centers. They need not, however, use the same airports as air carriers. Table 1, based on information supplied by Gulfstream, shows the airports where the 177 G2 aircraft are based in the U.S. 44 G2s are located at major air carrier levels, 40 at other airports with air carrier service, and 93 are based at general aviation airports. The largest concentration of G2s occurs at White Plans (26) and Teterboro (17), both serving the New York Metropolitan area. Both airports are major business jet bases. Additional G2s in the New York area are based at Newark (6), La Guardia (4), Bethpage (2), Morristown (1), and Islip (1).

Table 2, based on information supplied by Aviation Data Services, shows the 209 cities (as opposed to airports) where the 450 GE Learjets are based. The Learjets are not as concentrated as the G2s with 25 listed for Dallas, 24 for Houston, 16 for Fort Lauderdale, 9 for Van Nuys, 12 for Denver, 8 for Spirit of St.Louis (Chesterfield), and 8 for Lincoln. 270 of the 450 aircraft are based in eight states: Texas (85),

1/ The market could be increased if the aerodynamically improved Learjet 28/29 models gain acceptance. Sales of these aircraft have, however, been a minor part of total GE Learjet deliveries. A survey by Aviation Data Services listed only 5 Model 28/29 in the U.S. industry as of January 1, 1980.

TABLE 1

GULFSTREAM 2 FLEET BY BASED AIRPORT

Major Hubs			Other Air Carrier Airports			General Aviation			
IAH	Houston	9	BUR	Burbank	8	White Plans	26	Latrobe	2
EWR	Newark	6	DAL	Dallas Love	6	Teterboro	17	Phoenix	1
SFO	San Francisco	4	HOU	Houston Hobby	6	Mercer County	5	Morristown	1
LGA	La Guardia	4	TOL	Toledo	4	St. Paul Downtown	5	Aurora	1
MSP	Minneapolis	4	MDW	Midway	3	Willow Run	4	Ashland	1
PIT	Pittsburgh	3	LGB	Long Beach	2	Luken Cincinnati	3	Owensboro	1
DCA	National	3	OAK	Oakland	2	Detroit City	3	Bedford	1
BAL	Baltimore	2	ROC	Rochester	2	Atlanta Municipal	3	Darby Dan	1
ORD	O'Hare	2	SYR	Syracuse	1	Bethpage	2	Hook	1
DEN	Denver	2	BDL	Bradley	1	Duchess County	2	Bartlesville	1
LAX	Los Angeles	1	RNO	Reno	1	Palwaukee	2	Allegheney County	1
LAS	Las Vegas	1	ISP	McArthur	1	Cuyahoga County	2	Bethlehem	1
CLT	Charlotte	1	MLI	Moline	1	Johnson Space Center	2	Stevens Point	1
IND	Indianapolis	1	ORH	Worcester	1	North Philadelphia	2	Atlanta Brown	1
MKE	Milwaukee	1	INT	Winston-Salem	1				
	Total	44			40				93

TABLE 2

LEARJET INVENTORY BY CITY AND STATE
AS OF 1/31/80

City	LJ23	LJ24	LJ25	LT28/29	Total
Birmingham	0	1	1	0	2
Elba	0	0	1	0	1
Leufala	0	1	0	0	1
Fairhope	0	5	1	0	6
Montgomery	1	0	0	0	1
Muscle Shoals	0	1	0	0	1
Tuscaloosa	0	0	1	0	1
Alabama	1	8	4	0	13
Arkansas	0	0	0	0	0
Phoenix	1	0	0	0	1
Arizona	1	0	0	0	1
Azuza	0	1	0	0	1
Beverly Hills	0	0	1	0	1
Burbank	0	0	1	0	1
Burlingame	0	0	1	0	1
Camarillo	0	0	1	0	1
Carlsbad	1	0	1	0	2
Fresno	1	1	0	0	2
Goleta	0	1	1	0	2
Hawthorne	0	0	1	0	1
Irvine	0	1	1	0	2
Livermore	0	1	0	0	1

TABLE 2 (Continued)

LEARJET INVENTORY BY CITY AND STATE
AS OF 1/31/80

City	LJ23	LJ24	LJ25	LT28/29	Total
Long Beach	0	1	1	0	2
Los Angeles	1	0	2	0	3
Moffett Field	0	1	0	0	1
Ontario	0	0	2	0	2
Palm Springs	1	0	0	0	1
Pomona	0	0	2	0	2
Riverside	0	2	0	0	2
Sacramento	1	0	1	0	2
Salinas	0	1	0	0	1
San Diego	0	1	0	0	1
Santa Ana	1	1	0	0	2
Santa Monica	0	1	0	0	1
Santa Rosa	0	0	1	0	1
Van Nuys	1	6	1	1	9
Whittier	0	0	1	0	1
California	7	19	19	1	46
Denver	2	5	5	0	12
Englewood	0	1	0	0	1
Salida	0	1	0	0	1
Walsh	0	1	0	0	1
Colorado	2	8	5	0	15
Danbury	0	1	0	0	1
Ridgefield	0	0	1	1	2
Windsor Locks	1	2	0	0	3
Connecticut	1	3	1	1	6

TABLE 2 (Continued)

LEARJET INVENTORY BY CITY AND STATE
AS OF 1/31/80

City	LJ23	LJ24	LJ25	LT28/29	Total
Washington	2	0	1	0	3
District of Columbia	2	0	1	0	3
Delaware	0	0	0	0	0
Clearwater	0	0	1	0	1
Coral Gables	0	0	1	0	1
Fort Lauderdale	2	6	8	0	16
Fort Myers	0	0	1	0	1
Golden Beach	0	1	0	0	1
Lauderdale by Sea	0	1	0	0	1
Marianna	1	0	0	0	1
Melbourne	0	1	0	0	1
Miami	0	2	3	0	5
Orlando	1	0	1	0	2
Palm Beach	0	1	3	0	4
Satellite Beach	0	1	0	0	1
Tampa	1	0	0	0	1
West Palm Beach	0	3	0	0	3
Florida	5	16	18	0	39
Atlanta	0	3	0	0	3
Carrollton	0	0	1	0	1
McDonough	0	0	1	0	1
Savannah	0	0	2	0	2
Georgia	0	3	4	0	7

TABLE 2 (Continued)

LEARJET INVENTORY BY CITY AND STATE
AS OF 1/31/80

City	LJ23	LJ24	LJ25	LT28/29	Total
Davenport	0	0	1	0	1
Des Moines	0	0	2	0	2
Iowa	0	0	3	0	3
Boise	0	1	0	0	1
McCall	0	1	0	0	1
Idaho	0	2	0	0	2
Chicago	0	1	1	0	2
Danville	1	0	0	0	1
Franklin Park	0	0	1	0	1
Long Grove	0	1	0	0	1
Mount Vernon	0	0	1	0	1
Oak Brook	0	0	1	0	1
Rockford	0	0	1	0	1
Springfield	1	1	0	0	2
Wayne	0	1	0	0	1
Wheeling	2	1	0	0	3
Illinois	4	5	5	0	14
Batesville	0	1	0	0	1
Elkhart	1	0	0	0	1
Evansville	0	0	1	0	1
Oaktown	0	0	1	0	1
Terre Haute	0	1	0	0	1
Indiana	1	2	2	0	5

TABLE 2 (Continued)

LEARJET INVENTORY BY CITY AND STATE
AS OF 1/31/80

City	LJ23	LJ24	LJ25	LT28/29	Total
Lenexa	1	0	0	0	1
Wichita	0	1	2	1	4
Kansas	1	1	2	1	5
Lexington	0	0	2	0	2
Madisonville	1	0	0	0	1
Mt. Sterling	0	1	0	0	1
Kentucky	1	1	2	0	4
Houma	1	0	0	0	1
Lafayette	0	0	1	0	1
Shreveport	0	0	1	0	1
Louisiana	1	0	2	0	3
Bradford	1	0	0	0	1
South Hadley	0	0	1	0	1
Waltham	0	0	1	0	1
Massachusetts	1	0	2	0	3
Baltimore	0	0	1	0	1
Maryland	0	0	1	0	1
Maine	0	0	0	0	0

TABLE 2 (Continued)

LEARJET INVENTORY BY CITY AND STATE
AS OF 1/31/80

City	LJ23	LJ24	LJ25	LT28/29	Total
Detroit	2	0	1	0	3
Grand Rapids	0	4	0	0	4
Jackson	1	0	1	0	2
Oak Park	0	0	2	0	2
Ypsilanti	2	2	0	0	4
Michigan	5	6	4	0	15
Eden Prarie	0	1	1	1	3
Lakeville	0	1	0	0	1
Minnesota	0	2	1	1	4
Chesterfield	0	6	2	0	8
Kansas City	0	0	1	0	1
St. Louis	1	1	5	0	7
Missouri	1	7	8	0	16
Bay Saint Louis	1	0	0	0	1
Jackson	0	1	0	0	1
Laurel	0	1	0	0	1
Mississippi	1	2	0	0	3
Butte	0	0	1	0	1
Montana	0	0	1	0	1

TABLE 2 (Continued)

LEARJET INVENTORY BY CITY AND STATE
AS OF 1/31/80

City	LJ23	LJ24	LJ25	LT28/29	Total
Chapel Hill	0	0	1	0	1
Greensboro	0	1	1	0	2
Hickory	1	0	0	0	1
Lenoir	1	0	0	0	1
Morrisville	0	0	1	0	1
Winston-Salem	1	1	0	0	2
North Carolina	3	2	3	0	8
Lincoln	0	4	4	0	8
Omaha	0	2	1	0	3
Nebraska	0	6	5	0	11
Glen	0	1	0	0	1
New Hampshire	0	1	0	0	1
Florham Park	1	0	0	0	1
Princeton	1	0	0	0	1
Teterboro	2	1	0	0	3
Toms River	1	0	0	0	1
Wayne	0	0	1	0	1
New Jersey	5	1	1	0	7
Albuquerque	0	1	2	0	3
New Mexico	0	1	2	0	3

TABLE 2 (Continued)

LEARJET INVENTORY BY CITY AND STATE
AS OF 1/31/80

City	LJ23	LJ24	LJ25	LT28/29	Total
Las Vegas	1	3	0	0	4
Reno	0	1	2	0	3
Nevada	1	4	2	0	7
Buffalo	0	1	0	0	1
Garden City	0	1	2	0	3
Hudson	0	1	0	0	1
New York	0	2	2	0	4
Ogdensburg	0	1	0	0	1
Rochester	0	1	0	0	1
Syracuse	0	0	1	0	1
New York	0	7	5	0	12
Cincinnati	1	1	2	0	4
Cleveland	0	1	6	0	7
Columbus	0	10	4	0	14
East Palestine	0	1	0	0	1
Elyria	3	0	0	0	3
London	0	1	0	0	1
Napoleon	0	0	1	0	1
Swanton	0	0	2	0	2
Toledo	0	0	2	0	2
Youngstown	0	0	1	0	1
Ohio	4	14	18	0	36

TABLE 2 (Continued)

LEARJET INVENTORY BY CITY AND STATE
AS OF 1/31/80

City	LJ23	LJ24	LJ25	LT28/29	Total
Bethany	0	0	1	0	1
Oklahoma City	0	1	2	0	3
Tulsa	0	4	2	0	6
Oklahoma	0	5	5	0	10
Hillsboro	0	0	1	0	1
McMinnville	0	0	1	0	1
Medford	0	1	0	0	1
Newberg	0	1	0	0	1
Portland	1	1	1	0	3
Troutdale	0	1	1	0	2
Oregon	1	4	4	0	9
Allentown	0	0	1	0	1
Bala Cynwyd	0	0	1	0	1
Coatesville	1	0	0	0	1
Johnstown	0	1	0	0	1
Latrobe	0	1	0	0	1
Media	0	0	1	0	1
Milford	1	0	0	0	1
Philadelphia	2	0	0	0	2
Pittsburgh	0	1	3	0	4
Reading	0	1	0	0	1
Spring Mills	0	0	1	0	1
Valley Forge	0	0	1	0	1

TABLE 2 (Continued)

LEARJET INVENTORY BY CITY AND STATE
AS OF 1/31/80

City	LJ23	LJ24	LJ25	LT28/29	Total
West Mifflin	0	0	2	0	2
Willow Grove	0	0	1	0	1
Pennsylvania	4	4	11	0	19
Rhode Island	0	0	0	0	0
Greenville	0	1	1	0	2
Spartanburg	0	1	0	0	1
South Carolina	0	2	1	0	3
South Dakota	0	0	0	0	0
Lavergne	0	0	1	0	1
Memphis	1	2	2	0	5
Nashville	0	2	1	0	3
Sevierville	0	0	1	0	1
Smyrna	1	0	0	0	1
Tennessee	2	4	5	0	11
Abilene	0	1	3	0	4
Addison	0	1	1	0	2
Amarillo	0	2	0	0	2
Beeville	0	1	0	0	1
Conroe	0	1	0	0	1
Corpus Christi	0	0	0	1	1

TABLE 2 (Continued)

LEARJET INVENTORY BY CITY AND STATE
AS OF 1/31/80

City	LJ23	LJ24	LJ25	LT28/29	Total
Dallas	3	7	15	0	25
Frisco	0	0	1	0	1
Fort Worth	0	2	0	0	2
Houston	1	7	16	0	24
Lubbock	0	1	0	0	1
Menard	0	0	1	0	1
Midland	0	5	2	0	7
Pampa	0	0	1	0	1
San Angelo	0	0	1	0	1
San Antonio	2	6	3	0	11
Texas	6	34	44	1	85
Bountiful	0	1	0	0	1
Salt Lake City	0	0	1	0	1
Utah	0	1	1	0	2
Arlington	1	0	0	0	1
Charlottesville	0	0	1	0	1
Lynchburg	0	1	0	0	1
Norfolk	0	0	1	0	1
Richmond	0	2	1	0	3
Roanoke	0	0	1	0	1
Sandston	1	0	0	0	1
Virginia	2	3	4	0	9
Vermont	0	0	0	0	0

TABLE 2 (Continued)

LEARJET INVENTORY BY CITY AND STATE
AS OF 1/31/80

City	LJ23	LJ24	LJ25	LT28/29	Total
Kent	1	0	0	0	1
Richland	0	1	0	0	1
Seattle	0	3	0	0	3
White Swan	0	1	0	0	1
Washington	1	5	0	0	6
Grafton	0	1	0	0	1
Green Bay	0	1	1	0	2
Kohler	0	1	0	0	1
Milwaukee	0	0	2	0	2
Sheboygan	0	1	0	0	1
Wisconsin	0	4	3	0	7
Bluefield	0	1	0	0	1
West Virginia	0	1	0	0	1
Casper	0	0	1	0	1
Cheyenne	1	0	0	0	1
Gillette	0	1	0	0	1
Wyoming	1	1	1	0	3
Alaska	0	2	0	0	2
Hawaii	0	0	0	0	0
Total U.S.	65	186	194	5	450

Source: Aviation Data Services

California (46), Florida (39), Ohio (36), Pennsylvania (19), Missouri (16), Michigan (15), and Illinois (14).

Thus, with some exceptions, the aircraft are dispersed and many are based at airports with no air carrier service. It is also important to note that the utilization rate for business jets is substantially less than that for air carrier aircraft. Business jets' operating hours per year are in the 600-700 range while prime airline aircraft approach 3000 hours per year utilization. NBAA estimates that the average business flight takes approximately one hour so that a business jet would average about 600 departures per year. A 727, on the other hand, makes approximately 2400 departures per year.

This dispersion of aircraft and relatively low utilization rates tend to mitigate the seriousness of the noise impacts associated with business jets. Moreover, substantial noise reductions appear possible by flying safe by means of quieter noise abatement procedures. These are discussed below.

METHODS FOR ASSESSING NOISE IMPACTS

This analysis employs three criteria in the evaluation of noise impacts resulting from the operation of turbojet powered general aviation aircraft:

(1) EPNdB at the FAR 36 measuring points,

(2) EPNdB contour areas for single landing and takeoff cycles, and

(3) The number of landing and takeoff cycles necessary to add 1 dB of sound energy to the 30 NEF contour.

EPNdB at the FAR 36 measuring points gives an indication of the ability of a specific aircraft to meet Stage 3 of FAR 36, and consequently is referred to as the "compliance" criterion. The two criteria which involve the use of EPNdB and NEF contour area reflect the

extent and location of varying levels of noise impact as aircraft are operated from typical airports, and are referred to as "community impact" criteria. Since the objective of the FAR 36 regulations is ultimately to reduce community noise impact, both types of criteria are useful in evaluating the effect of early implementation of Stage 3 of FAR 36.

In previous work,[1/] JWN has used the 100 and 90 EPNdB contours to represent "close in" and "far out" single event noise impact. The approach has been replaced by a new analytical technique called the Area Equivalent Method (AEM).

The AEM is based on the relationship between EPNdB and contour area over a range of EPNdB values. In order to accomplish this, the FAA Integrated Noise Model (INM) was used to determine the 85, 90, 95, 100 and 105 EPNdB contour areas resulting from one landing and one takeoff (one LTO cycle) of each aircraft type analyzed. A log linear regression of EPNdB versus area then gave a relationship between area and EPNdB, with R^2s exceeding .9933 in all cases.

The AEM analysis of the Gulfstream 2 with untreated Spey engines will serve as an example. The INM estimates of contour impact areas for a single LTO cycle of the Gulfstream 2 at maximum takeoff and landing weights are given as follows:

EPNdB	Contour Area (Sq. Mi.)
85	70.34
90	27.35
95	10.52
100	3.79
105	1.55

[1/] C.F. Day and E.D. Studholme, "Inputs to CAB Environmental Impact for Multiple Permissive Entry," FR-1501-CAB, April 1979.

The log linear regression of EPNdB versus contour area results in the equation; Log (AREA) = 8.94194 - .08344 (EPNdB), which predicts the INM estimates quite accurately (R^2 = .9997), as shown by the following comparison:

EPNdB	Regression Areas	INM Areas
85	70.70	70.34
90	27.05	27.35
95	10.35	10.52
100	3.96	3.79
105	1.51	1.55

The same data may also be used to determine the relationship between 30 NEF area and the number of LTO cycles. Since:

$$\text{NEF} = \text{EPNdB} + 10 \text{ Log N} - 88$$

Then,

$$\text{N} = \text{Antilog } \frac{\text{NEF} + 88 - \text{EPNdB}}{10}$$

and the following table may be constructed:

N (LTO)	NEF	EPNdB	G2 Area
1995.26	30	85	70.70
630.96	30	90	27.05
199.53	30	95	10.35
63.10	30	100	3.96
19.95	30	105	1.51

The values of N may then be subjected to regression analysis against the INM estimated areas to obtain the equation: Log (30 NEF AREA) = -.904118 + .83441 (Log LTO) or, more simply:

$$30 \text{ NEF AREA} = .12470\ (\text{LTO})^{.83441}$$

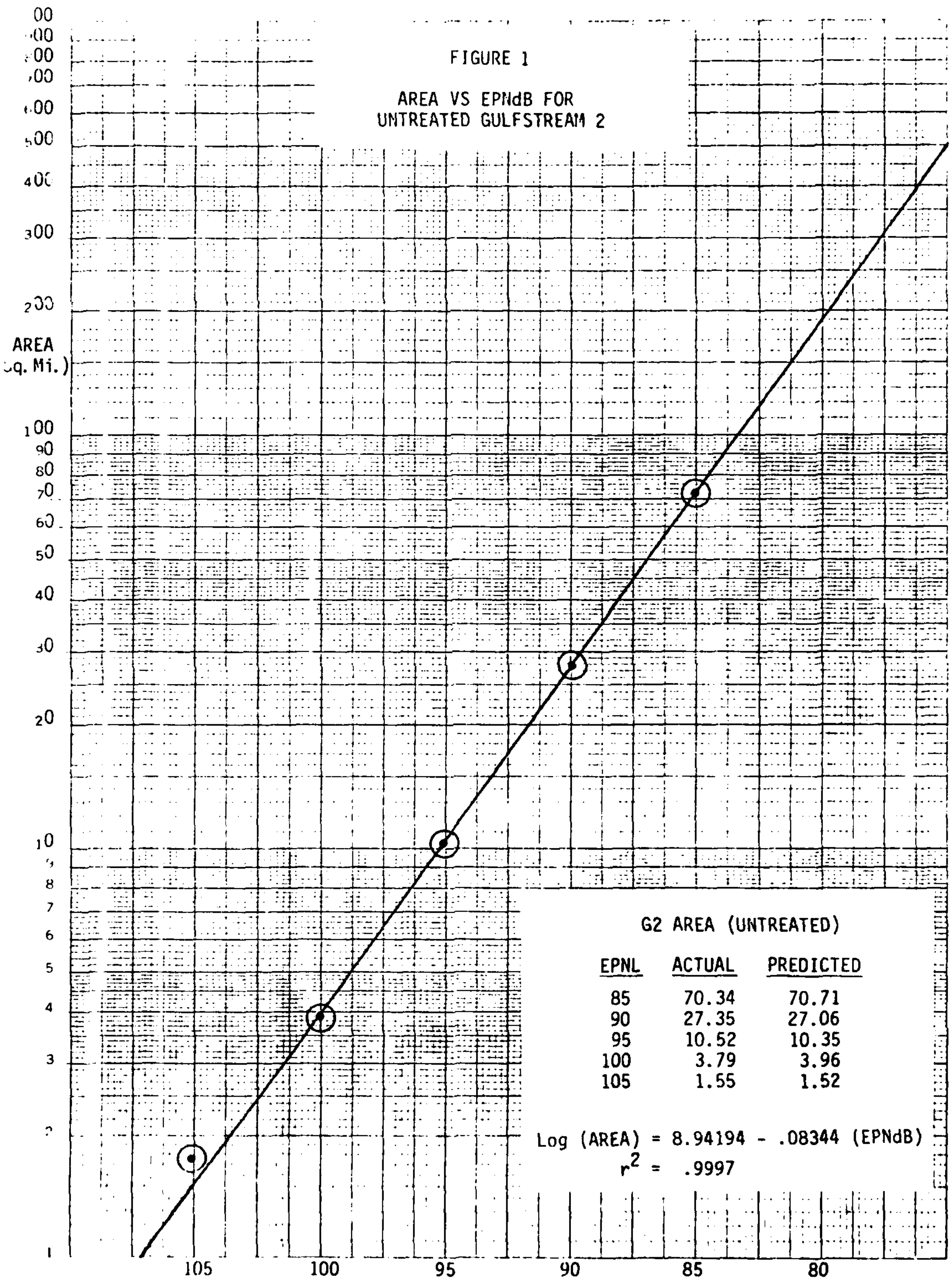
This interesting relationship may be graphed on Log-Log paper, where the listed values of N and EPNdB are equated on the horizontal axis, and both EPNdB and NEF area are the vertical axis. Figure 1 presents this relationship for the Gulfstream 2 example.

The ability to predict 30 NEF area is important, because it also permits accurate estimation of "Area Equivalent" LTO cycles -- the number of LTO cycles that must occur to generate a given NEF area. Where a is the area generated by one LTO and b is the exponent in the expression, Area = $a(\text{LTO})^b$, LTO is given by:

$$\text{LTO} = \left(\frac{\text{Area}}{a}\right)^{\frac{1}{b}}$$

In the Gulfstream 2 example, a is .12470 and b is .83441, so it would take 191.43 "Area Equivalent" LTO cycles by this aircraft to generate a 10 square mile 30 NEF contour:

$$\begin{aligned} \text{LTO}_{G2} &= \left(\frac{10}{.12470}\right)^{\frac{1}{.83441}} \\ &= (80.19)^{1.19845} \\ &= 191.43 \end{aligned}$$



G2 AREA (UNTREATED)

EPNL	ACTUAL	PREDICTED
85	70.34	70.71
90	27.35	27.06
95	10.52	10.35
100	3.79	3.96
105	1.55	1.52

$$\text{Log (AREA)} = 8.94194 - .08344\ (\text{EPNdB})$$
$$r^2 = .9997$$

The addition of any number of LTO cycles of this aircraft to an airport with any existing 30 NEF impact area now has a predictable impact, which may be expressed in decibels. If, for example, we add 20 maximum weight Gulfstream 2 LTO cycles to an airport with an existing 30 NEF area of 10 square miles, the impact is given by:

$$\Delta dB = 10 \text{ Log } [(N_1/N_2) + 1],$$

where ΔdB is the change in sound pressure level, N_1 is the number of new LTO cycles, and N_2 is the "Area Equivalent" LTO cycles. The 10 square mile reference area and 20 new LTO cycles give:

$$\begin{aligned} \Delta dB &= 10 \text{ Log } [(20/191.43) + 1] \\ &= 10 \text{ Log } [1.104477] \\ &= 0.43 \end{aligned}$$

This indicates an increase of 0.43 dB in the 30 NEF contour, making the new 10 square mile contour 30.43 NEF.

Conversely, the number of LTO cycles necessary to add ΔdB to a given 30 NEF area is given by: $N_3 = N_2 * [(\text{Antilog } \Delta/10) - 1]$, or in the example:

$$\begin{aligned} N_3 &= 191.43 * [(10^{1/10}) - 1] \\ &= 191.43 * (.2589) \\ &= 46.57 \end{aligned}$$

In other words, it would take 46.57 LTO cycles of the maximum weight Gulfstream 2 with untreated Spey engines to add 1 dB to the 30 NEF area at an airport with an existing 10 square mile 30 NEF impact area. This relationship may also be graphically depicted, as in Figure 2.

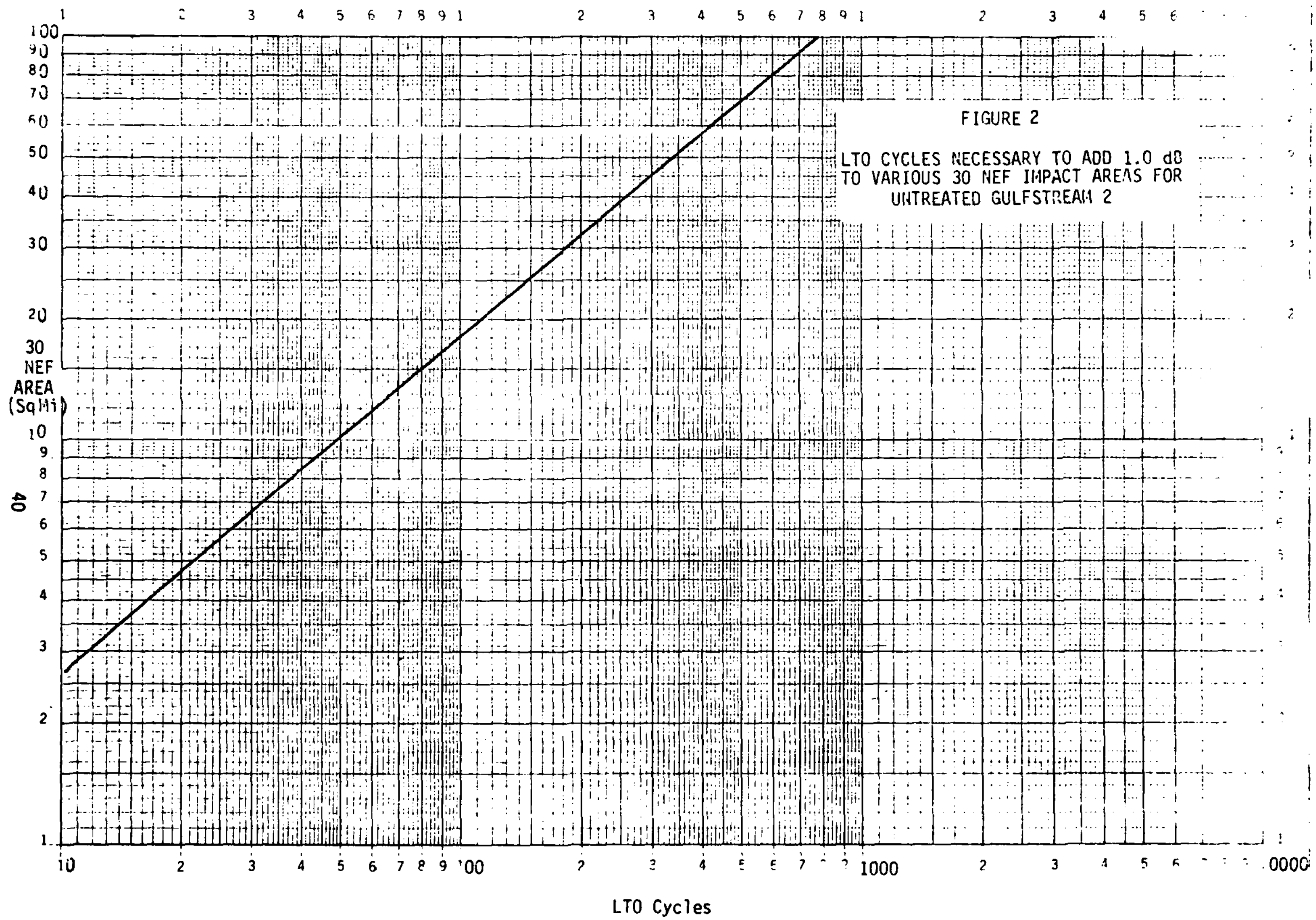


FIGURE 2

LTO CYCLES NECESSARY TO ADD 1.0 dB TO VARIOUS 30 NEF IMPACT AREAS FOR UNTREATED GULFSTREAM 2

Both the EPNdB area and the LTO cycle community noise impact criteria are very useful in assessing the community impacts resulting from the operation of turbojet powered general aviation aircraft from various types of airports, especially when comparisons are made between different types of aircraft. JWN has conducted the AEM analysis for several different aircraft types to provide a basis for such comparison, and to facilitate the accurate characterization of the community noise impacts likely to result from the operation of general aviation aircraft which are unable to meet Stage 3 of FAR 36. This analysis includes:

Aircraft	Stage Length	Takeoff Procedure
G2 Untreated 1/	Maximum	Standard
G2	Maximum	Standard
G2	1500 Miles	Noise Abatement
G3	Maximum	Standard
G3	Maximum	Noise Abatement
G3	1500 Miles	Noise Abatement
Learjet 24/25	500 Miles	Standard

JWN has also included AEM analyses of the 727, 737, DC9 and A300 aircraft completed in previous work for the CAB. 2/ This permits the calculation of the noise impact equivalency between several reference civil aircraft and the Learjet and Gulfstream aircraft for a variety of airports.

NOISE IMPACTS

As previously discussed, the GE Learjet and the Gulfstream 3 (G3) are the only current production general aviation aircraft which will be

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1/ All other G2 and G3 scenarios are for aircraft equipped with hush kits.

2/ C.F. Day and E.D. Studholme, "Inputs to CAB Environmental Impact for Multiple Permissive Entry," FR-1501-CAB, April 1979.

unable to meet Stage 3 of FAR 36, and which will also be in production after the "early implementation" date. Table 3 presents the FAR 36 EPNdB values for the Learjet 24D and G3 aircraft at maximum takeoff weight. The Learjet 24D represents the lowest EPNdB values obtained by any current production GE Learjet, and therefore, presents the best case. The G3 has measured FAR 36 values which differ very little from the G2 -- the G3 is 9.90 dB lower on approach because of improved aerodynamics and resultant reduced thrust, and 0.45 dB higher on takeoff, because of increased weight. No improvement in measured FAR 36 levels may be expectd for the G3 or GE Learjet by the early implementation date.

However, the community noise impact analysis indicates that "quiet-flying" mitigation measures can be very effective, and deserve careful consideration. Figure 3 presents impact area as a function of EPNdB for several types of aircraft, including the Learjet 24/25, the G2 and the G3. EPNdB area functions are also presented for the 727, DC9 and A300, for purposes of community impact comparison.

The old untreated G2 is a very noisy aircraft, equalling the DC9's impact area at 105 EPNdB, and remaining within 2.6 dB of the 727 all the way out to 85 EPNdB. The old G2 impact area is 56% greater than the DC9 at 90 EPNdB and 75% greater at 85 EPNdB.

The G3, at 68,000 pounds, is 4 to 5 dB quieter than the old G2, due to the use of "hush-kit" equipped Spey engines. This results in a 55-60% reduction in area for all EPNdB values. The same G3, using a Gulfstream developed noise abatement departure procedure, gives an additional 24% reduction at 100 EPNdB, and over 51% at 85 EPNdB. At a 50,000 pound takeoff weight, using the noise abatement departure procedure, the G3 very closely approximates the EPNdB area functon of the A300 -- the quietest aircraft in the air carrier jet fleet.

These results are somewhat surprising, because it is generally believed that thrust reductions on takeoff for noise abatement tend to reduce noise impact "near-in," while increasing impact farther out, due

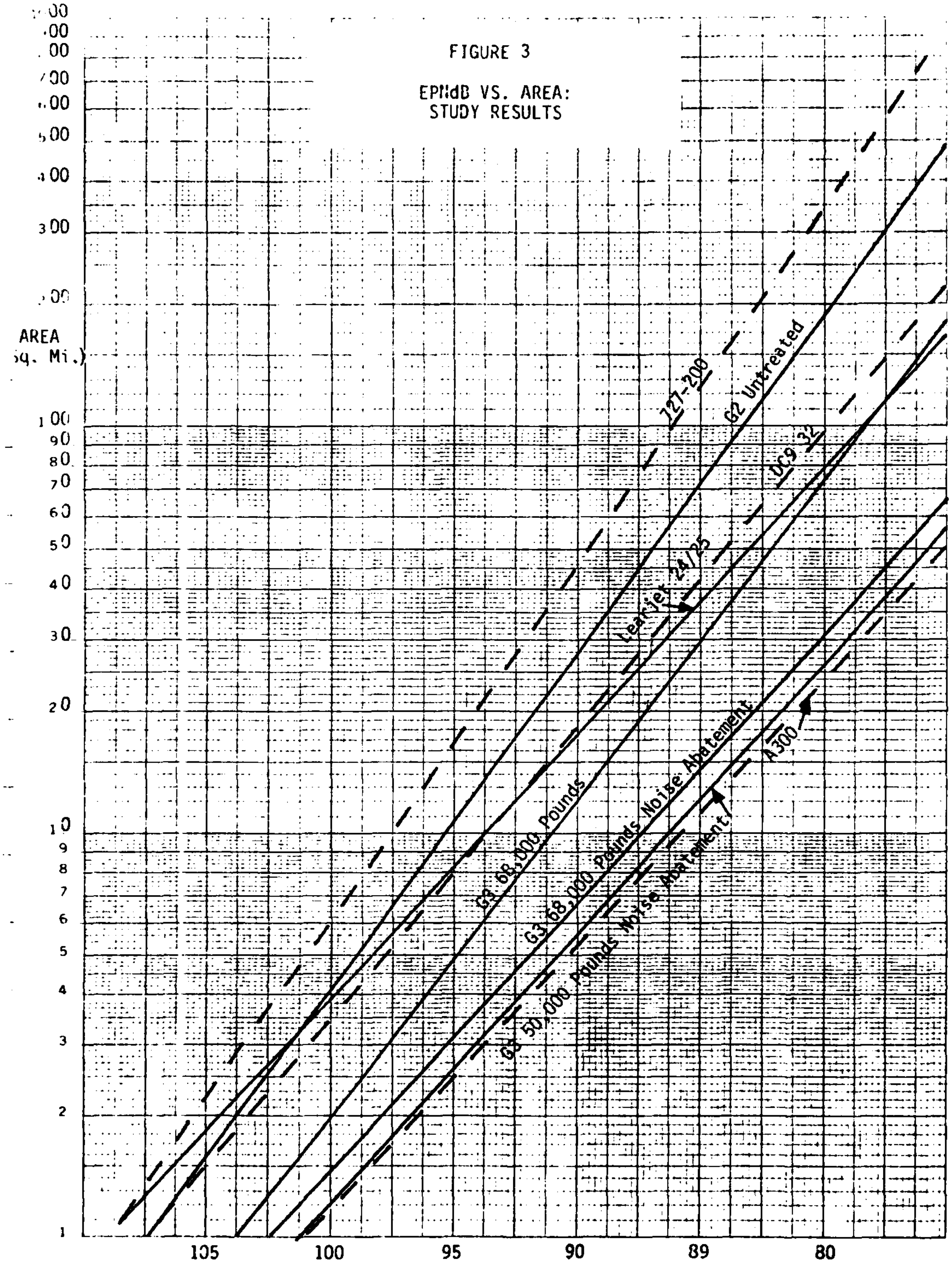
TABLE 3

MEASURED FAR 36 EPNdB VALUES FOR
MAXIMUM WEIGHT GULFSTREAM 3 AND LEARJET 24D

	G3	STAGE 3 FAR 36	LEARJET 24D
Takeoff	91.33	89	90.1
Sideline	102.91	94	97.3
Approach	97.29	98	100.7

FIGURE 3

EPNdB VS. AREA:
STUDY RESULTS



to reduced trajectories, i.e., smaller 100 EPNdB and larger 90 EPNdB areas. For the G3, this clearly is not the case.

This is due, primarily to the high thrust to weight ratio of the G3, which permits substantial thrust reductions without unduely compromising maneuverability or safe climb performance. With a 53% reduction in thrust, the 68,000 pound G3 can maintain a climb gradient of over .075 at a constant 163 kta. velocity. Since noise emissions from the Spey 511-8 engines are quite sensitive to thrust, such reduced thrust takeoff procedures prove to be very effective in limiting community noise exposure. Gulfstream American has developed and test flown a number of noise abatement procedures which take advantage of the operating flexibility of the G2 and G3.

Only one takeoff procedure was simulated for the Learjet 24/25 because no established alternative takeoff procedures were available from the manufacturer. In order to reflect the impact of a typical LTO cycle, a 0-500 mile stage length was used in the INM simulation. Figure 3 reveals that the standard takeoff procedure results in very large 105 and 100 EPNdB contours, with substantial impact areas out to the 85 EPNdB contour. Down to 92 EPNdB, the Learjet 24/25 areas exceed those of the DC9-32, and from 92 to 85 EPNdB, the DC9-32 areas are slightly greater. At 100 EPNdB, the Lears are 100% larger than a G3 flying 3,800 miles, and at 90 EPNdB, they are 42% greater.

Figure 4 presents the number of LTO cycles that it would take to add 1 dB to the 30 NEF impact areas at airports having existing 30 NEF impact areas ranging from 1.0 to 100.0 square miles. Note that the right vertical axis indicates the 1978 estimate 30 NEF impact areas for four classes of civil airports:[1/]

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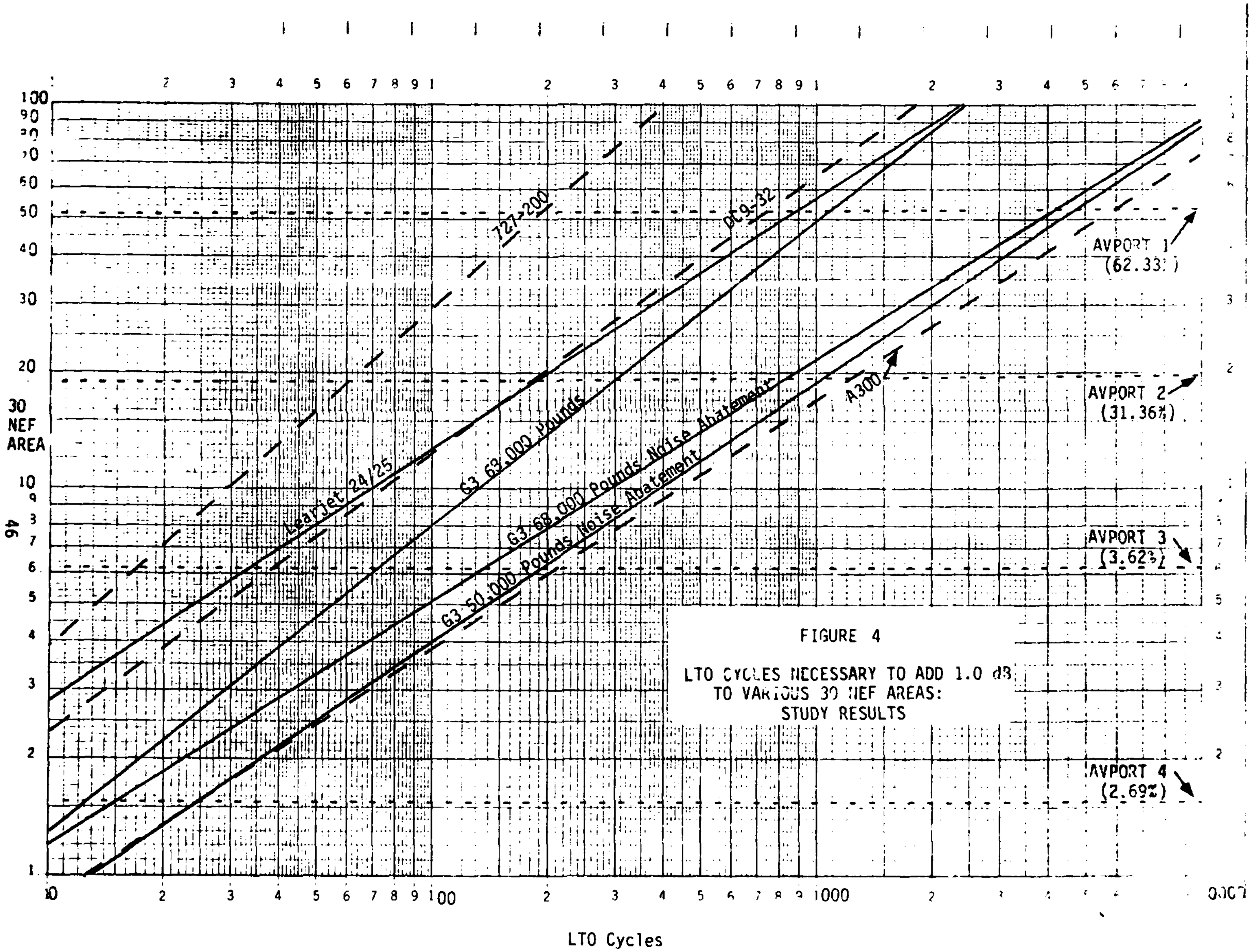


FIGURE 4

LTO CYCLES NECESSARY TO ADD 1.0 dB TO VARIOUS 30 NEF AREAS: STUDY RESULTS

1. AVPORT 1 airports with 250 or more air carrier departures per day
2. AVPORT 2 airports with 50 to 249 air carrier departures per day
3. AVPORT 3 airports with 20 to 49 air carrier departures per day
4. AVPORT 4 airports with 5 to 19 air carrier departures per day

The percentage of the national total population impacted in each class is indicated in parentheses.

For example, the largest class of airports, AVPORT 1 accounts for 62.3% of the total national population exposed to 30 NEF or greater. Airports in the AVPORT category generated a 30 NEF contour averaging 53 square miles in 1978. It would take 200 727, 760 DC9, or 5800 A300 LTO cycles to generate a 1 dB impact at 30 NEF for this class of airports. A single night LTO cycle would have a 1 dB impact only at or below the AVPORT 3 category, which contains only 3.62% of the populations.

The Learjet 24/25 and G3 functions are quite revealing. 1 dB impacts at the large AVPORT 1 airports will not occur until 940 Learjet 24/25 or 1,120 G3 average daily LTO cycles occur -- clearly an impossibility at a single airport. For the G3 using the noise abatement procedure, this number approaches or exceeds 4,000 LTO cycles, depending on aircraft weight. On an aircraft equivalency basis, this means that one 727 LTO cycle has the same impact as 4.7 Learjet 24/25s, 5.6 G3s using the standard takeoff procedure or 20 G3s using the noise abatement procedure.

These figures change somewhat for the smaller AVPORT 2 category airports, which have a 19.1 square mile 30 NEF impact area, and account for 32.4% of the 30 NEF impacted population. Here, 67 727, 180 DC9, 190 Learjet 24/25, or 300 G3 LTO cycles would be necessary to add 1 dB to the 30 NEF area. The G3 using noise abatement would require between 820 and 1,000 LTO cycles to add 1 dB, depending on weight. On an aircraft equivalency basis, this indicates that one 727 LTO cycle equals 2.8 Learjet 24/25s, 4.5 G3s using the standard takeoff procedure, or 15 G3s using the noise abatement procedure.

AVPORT 3 has a 6.3 square mile 30 NEF impact area, and accounts for 3.6% of the 30 NEF impacted population. AVPORT 3 will not experience a 1 dB increase in 30 NEF area until 17.0 727 LTO cycles occur. This is significant, because one night LTO cycle by a 727 will almost generate a 1 dB impact. About 35 Learjet 24/25, 39 DC9 or 70 G3 LTO cycles would cause a 1 dB impact in the AVPORT 3 30 NEF contour. Between 143 and 195 G3 LTO cycles could occur if the noise abatement takeoff procedure is used, depending on aircraft weight. At the AVPORT 3 airports, one 727 LTO cycles equals 2.0 Learjet 24/25, 2.3 DC9 or 4.2 G3 LTO cycles. It would take 8.4 standard and as many as 11.5 "noise abatement" G3 LTO cycles to equal the impact of one 727 LTO cycle at airports in the AVPORT 3 category.

AVPORT 4 has a 1.5 square mile impact area, and accounts for 2.7% of the total national population exposed to 30 NEF or greater. 1 dB impact will result from 3.4 727, 3.9 Learjet 24/25, 5.4 DC9, or 12.0 G3 LTO cycles. The G3 noise abatement option increases this to 24.9 or 23.2 LTO cycles, depending on aircraft weight. At these small airports, one 727 LTO cycle equals 1.15 Learjet 24/25, 1.6 DC9, or 3.5 G3 LTO cycles. The 50,000 pound G3 using noise abatement is indistinguishable from the A300 as both have a 6.8 to 1 727 equivaliency. The 68,000 pound G3 using noise abatement is much closer to the standard takeoff G3 at a 4.4 to 1 727 equivalency.

The potential for significant community impact as a result of increases in operations by general aviation jet aircraft which cannot comply with Stage 3 of FAR 36 is very small for AVPORT 1 and 2 airports, but increases steadily as a function of decreasing airport size. Significant impact is most likely to occur at AVPORT 4 category airports. In 1978 there were 130 airports in AVPORT 4, impacting 124,000 people with 30 NEF or greater. A single night LTO G3 or Learjet 24/25 would add more than 1 dB to the 1978 30 NEF contour area at these airports, and the distinction between the 727 and Learjet 24/25 becomes

very small. The G3 does well at intermediate stage lengths (500-1500 miles) requiring takeoff weights of up to 50,000 pounds, provided that noise abatement departure procedures are used. In fact, this configuration compares favorably with the A300 operating at a 500 mile stage length.

Table 4 summarizes all of the community noise impact data developed for this report. It presents (1) impact area contained in 30 NEF contour, (2) impact area as a function of NEF, (3) NEF area as a function of LTO cycles, (4) LTO cycles necessary to equal 30 NEF area, and (5) LTO cycles necessary to add 1 dB to 30 NEF area.

POTENTIAL FOR FURTHER REDUCTIONS IN FAR 36

Most business jet aircraft currently in production easily meet Stage 3 requirements. Figure 5 shows aircraft sound levels for the three FAR 36 measurement points. It appears that Stage 3 limits could be reduced with only a small impact except for the GE Learjets and Gulfstream 3. From Figure 5, one could infer that the following reductions in noise limit are possible:

Point	From	To
Approach	98 dB	96 dB
Sideline	94	90
Takeoff	89	87

Note that Learjet Models 35 and 36 require tradeoffs to meet the Stage 3 standard and would not comply with the lower approach standard. The aircraft would, however, be at least 2 dB less than the reduced standards at the other measurement points. A revision of the tradeoff methods might be in order since the approach standard has less impact on community noise levels than either the sideline or takeoff standard.

TABLE 4

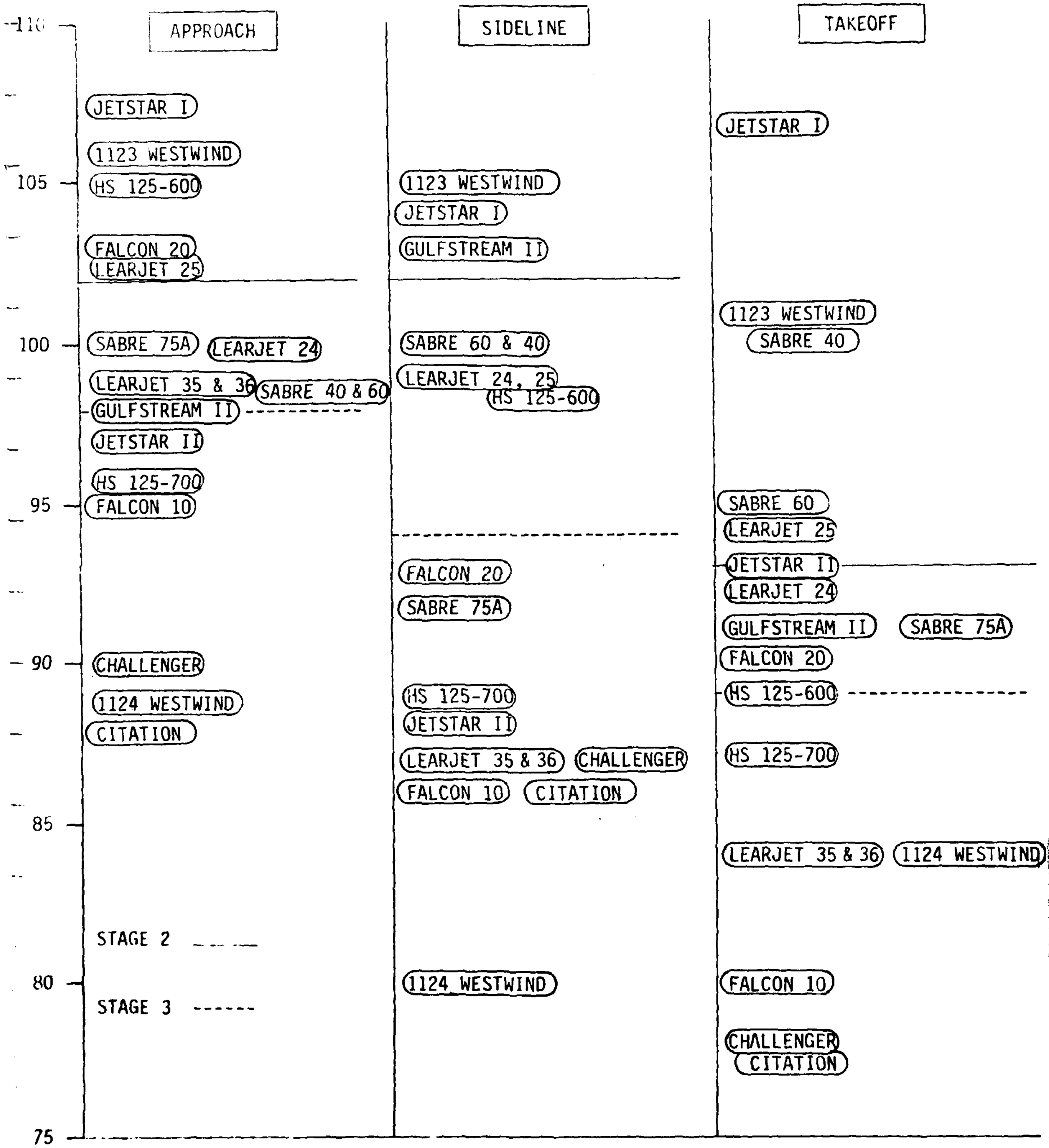
SUMMARY OF COMMUNITY IMPACT VALUES

Aircraft			G2 without Hush Kit	G2 With Hush Kit	G3	G2	G3	G3	Learjet 24/25	727-200 With SAM	DC9-32	737-200	A300
Takeoff Procedure			STD	STD	STD	noise abatement	noise abatement	noise abatement	STD	STD	STD	STD	STD
Weight			62,000	62,000	68,000	51,000	50,000	68,000	15,000	155,000	100,000	103,000	290,000
Stage Length			MAX	MAX	MAX	1,500	1,500	MAX	MAX	500	500	500	500
Impact Areas:													
30 NEF LTO		EPNdB											
1995.26	=	85	70.34	28.11	30.16	13.39	13.04	15.59	36.36	122.68	40.12	23.60	11.06
630.96	=	90	27.35	11.27	12.07	5.54	5.35	6.50	17.06	44.79	17.49	11.12	5.21
199.53	=	95	10.52	4.12	4.41	2.40	2.31	2.91	7.80	16.35	7.62	5.24	2.45
63.09	=	100	3.79	1.61	1.75	1.19	1.14	1.57	3.82	5.97	3.32	2.47	1.16
19.95	=	105	1.55	0.76	0.85	0.62	0.60	0.84	1.82	2.18	1.45	1.16	0.55
Log (NEF 30 AREA) = $a(LTO)^b$													
a =			.12470	.06446	.07308	.07741	.07404	.11670	.25698	.15878	.16729	.16447	.07707
b =			.83441	.79624	.78774	.66735	.66914	.63083	.65020	.87515	.72119	.65358	.65354
r^2 =			.999	.997	.997	.995	.995	.993	.999	.999*	.998*	.999*	.993*
LTOs to = 1 dB at 30 NEF at:													
10 square miles			49.57	146.03	133.33	377.31	395.48	300.08	72.20	29.45	75.24	138.86	443.07
25 square miles			148.61	461.56	426.68	1489.34	1555.33	1282.59	295.48	83.89	268.07	564.23	1900.39
50 square miles			341.06	1102.27	1028.62	4208.00	4382.27	3848.16	857.99	185.22	700.89	1629.41	5199.75
LTOs to = 30 NEF AREA of:													
10 square miles			191.43	564.05	515.00	1457.34	1527.52	1159.00	278.87	113.73	290.62	563.35	1711.35
25 square miles			574.02	1782.76	1648.08	5752.55	6007.47	4953.64	1141.30	324.03	1035.41	2179.23	6954.01
50 square miles			1317.32	4257.52	3973.32	16253.36	16926.51	14863.50	3314.00	715.43	2707.21	6293.57	20083.09

* Areas presented for the 727, DC9, 737 and A300 are predicted from the indicated regression equations. R^2 values reflect the correlation of these values with areas estimated by the INM.

FIGURE 5

AIRCRAFT SOUND LEVELS



SOURCES: HS 125-700, Business and Commercial Aviation, Jan. 1977; Challenger, Published Brochure; All Other, Advisory Circular 36-1B

OTHER ISSUES

A change in noise regulations to require new production aircraft to meet Stage 3 noise limits could have serious adverse impacts. These include:

1. Economic impacts on Gulfstream American and the subcontractors producing the G3 aircraft. It is doubtful that the company can survive if the G3 cannot be produced. In that event, the Savannah area would lose approximately 2,700 jobs with ripple effects upon G3 subcontractors. Total worth of the G3 program in 1980 dollars is about $4.1 billion for the years 1980-89.

2. Balance of Trade deficits could be increased if users opt to buy the Challenger or Falcon 50 instead of the G3.

3. The Utilization of Older Business Jets could be seriously disrupted. Many airports seek to exclude non-FAR 36 aircraft. A change that required all new aircraft to meet Stage 3 limits could be used to exclude all Stage 2 aircraft from certain airports. Since Stage 2 aircraft are a substantial portion of the business fleet, such rules could have a serious impact on business flying.

APPENDIX A

Appendix A contains the 90 and 100 EPNdB contours for Learjet 24/25, Figure 1, and Gulfstream 3, Figure 2. These aircraft could still be in production after 1985, however, they do not meet Stage 3 FAR 36 noise standards.

Figure 1 depicts the noise impact of the Learjet 24/25 operating at a takeoff weight of 15,000 pounds using a standard takeoff procedure. Figure 2 depicts the noise impact of the Gulfstream 3 operating at a takeoff weight of 68,000 pounds using a standard takeoff procedure.

FIGURE 1

LEARJET 24/25 90 AND
100 EPNdB CONTOURS

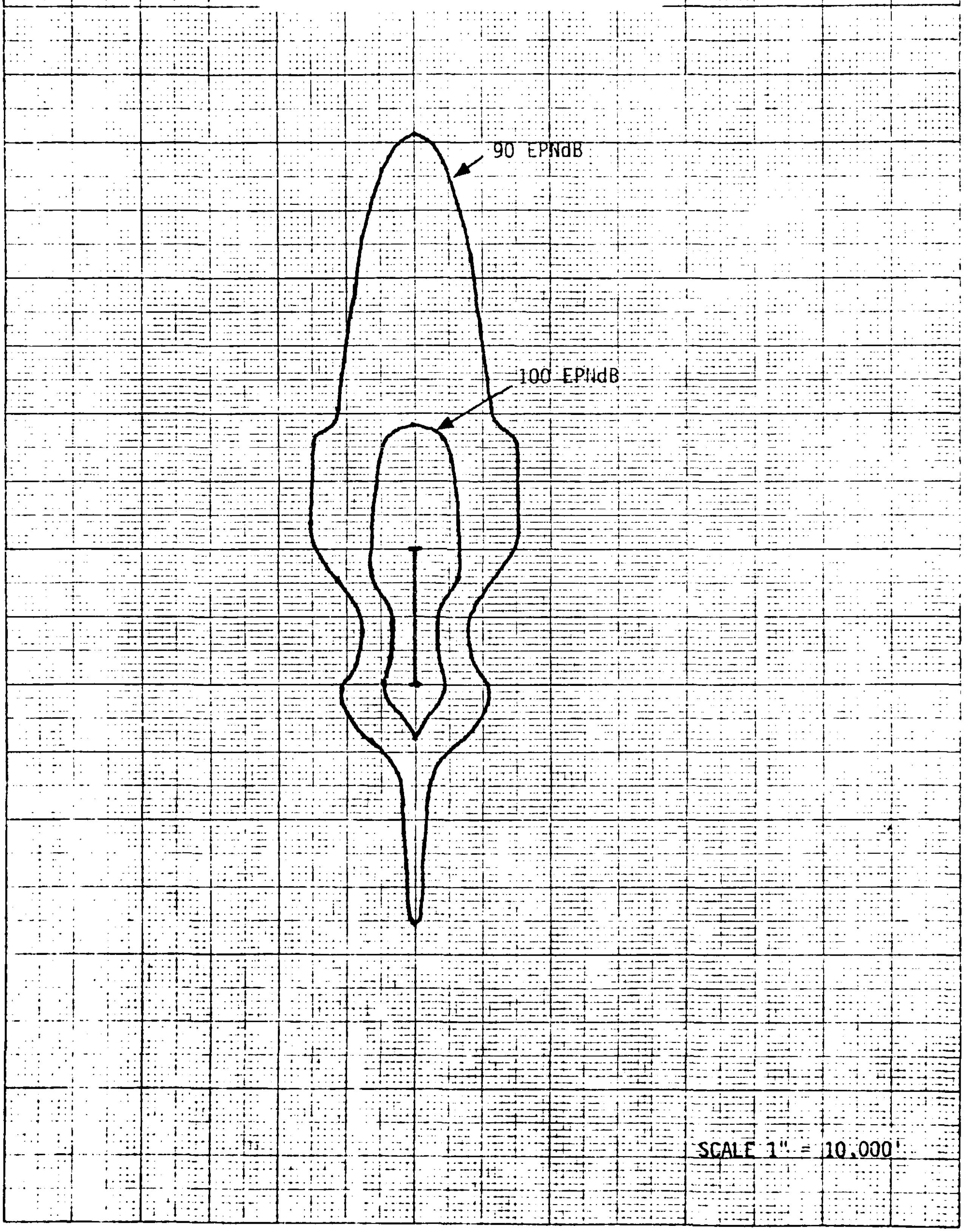
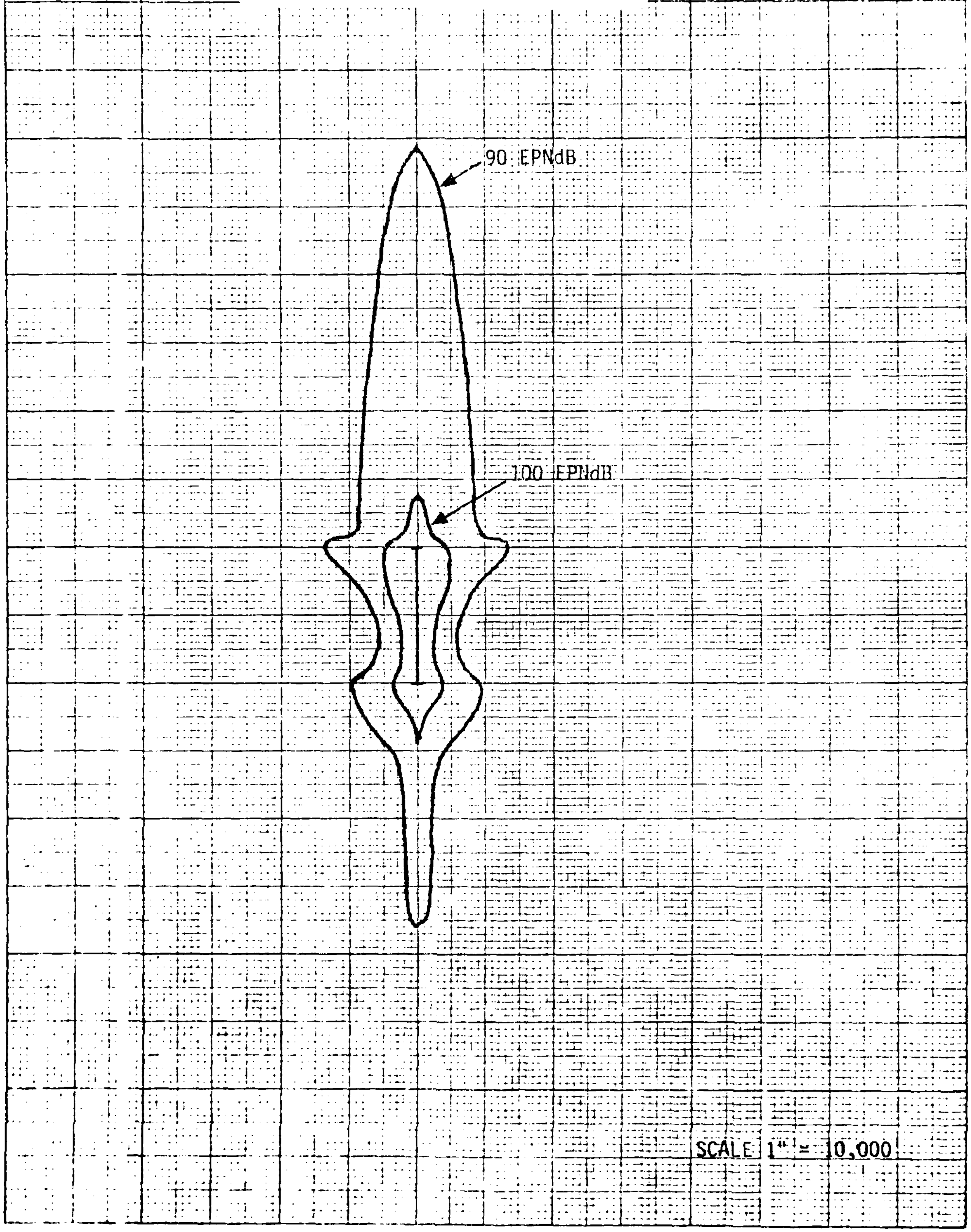


FIGURE 2

GULFSTREAM 3 90 AND
100 EPNdB CONTOURS

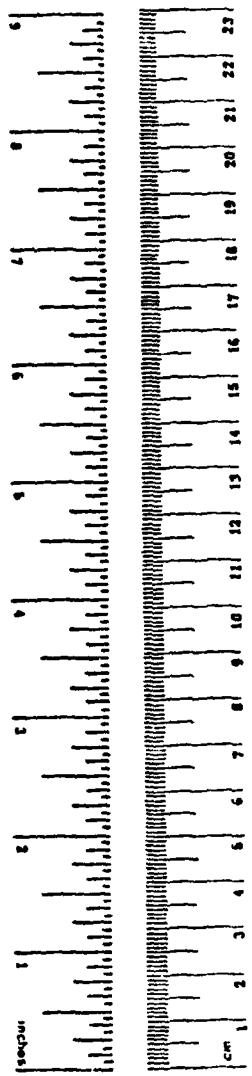


METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F